Accurate citizen monitoring of waterways using inexpensive conductivity meters

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Abstract

Conductivity is highly correlated to aquatic ecosystem health and is an accessible parameter for citizen scientists to measure. However, professionals often perceive citizen scientists' conductivity data as lower quality because their equipment is typically not as sophisticated. This study asked water professionals to compare conductivity readings from professional Yellow Springs Instrument probes with those taken by an inexpensive and widely available conductivity meter. Results show a strong correlation (R2 = 0.995) between the two datasets. Additionally, a long-term reproducibility trial determined the device's ability to maintain accurate results over time. By testing this inexpensive device for accuracy and consistency, the data is more likely to be seen as legitimate and is thus more likely to be used in decision-making processes.

Keywords: citizen science, conductivity, water quality, data deficiency

Résumé

La conductivité est fortement corrélée à la santé des écosystèmes aquatiques et est un paramètre facilement mesurable par des scientifiques citoyens. Cependant, les données de conductivité des scientifiques citoyens sont souvent perçues comme étant de qualité inférieure car l'équipement qu'ils utilisent n'est généralement pas aussi sophistiqué que celui des professionnels. Cette étude a fait appel aux professionnels de l'eau pour comparer les lectures de conductivité des sondes professionnelles Yellow Springs Instrument avec celles prises par un conductimètre peu coûteux et largement disponible. Une forte corrélation (R2 = 0,995) entre les deux ensembles de données a été trouvée. De plus, un essai de reproductibilité à long terme a été mené pour déterminer la

capacité de l'appareil peu coûteux à maintenir des résultats précis au fil du temps. En testant la précision et la cohérence de cet appareil, les données que les scientifiques citoyens collectent en l'utilisant sont plus susceptibles d'être considérées légitimes et ont donc plus de chance d'être utilisées dans les processus de prise de décision.

Introduction

Assessing water quality is not a simple task; aquatic ecosystems are heterogeneous and complex. While no one parameter is sufficient for evaluating overall water quality, research has shown that specific conductance (hereafter referred to as conductivity) frequently correlates with it (Brown et al. 2009). For example, a study of nine metropolitan areas in the USA found that 'specific conductance was the most consistent indicator of water quality' (Brown et al. 2009, 1059). Researchers have also noted strong correlations between Water Quality Indices (WQI), which aggregate a large number of variable data into a single number, and conductivity (Singh and Kamal 2014; Alobaidy et al. 2010). Studies have also found direct relationships between benthic health and conductivity levels; Clements and Kotalik's (2015) study shows a conductivity range from 280 to 29,000 µS/cm is inversely related to different species' survival rates. Thus, conductivity levels can potentially provide insight into ecosystem health as a whole.

Gaining insight into overall water quality is especially pressing in the Canadian context, where extensive data deficiencies remain a barrier to implementing well-informed water policies (WWF-Canada 2017). According to the first edition of World Wildlife Fund (WWF) Canada's *Watershed Reports* (2017), only 67 of 167 sub-watersheds in Canada had enough water quality data to determine their health. The 2020 version of WWF's *Watershed Reports* revealed similar findings: while the situation had improved slightly, 100 out of 167 sub-watersheds still lacked enough data to assess their overall health. While the reasons for this are many, one of the simplest is that professional scientists cannot monitor the millions of waterbodies in Canada on their own (Quinlivan et al. 2020).

One way to overcome the problems associated with data deficiencies is through citizen science, which refers to the participation of non-experts in scientific activities (Buytaert et al. 2016; Bonney et al. 2014). Traditionally, water testing requires expensive equipment, complicated sampling protocols, and adequate scientific literacy to interpret data. However, several tools have emerged in recent years that reduce these barriers. For example, conductivity has become an accessible parameter for citizen scientists to monitor. Inexpensive conductivity probes used by non-experts require less training and calibration than for other parameters, such as those requiring the use of reagents or laboratory facilities. In recognition of this, platforms such as Canadian-based Water Rangers (waterrangers.ca) have started to include the use of inexpensive conductivity probes into their citizen science protocols.

Unfortunately, citizen science is not always exploited to its full potential, as decision-makers sometimes perceive the data collected by citizen scientists as being inaccurate and, as a result, inadmissible (Thornton and Leahy 2012). In response to this, several studies have shown that citizen scientists can collect accurate, high-grade water quality data, provided they are equipped with sufficient training and proper resources (Quinlivan et al. 2020; Thornhill et al. 2018; Levesque et al. 2017). Similarly, research has shown that citizen scientists' and professional conductivity measurements frequently share a high agreement, even more so than for other parameters (Albus et al. 2020; Storey et al. 2016).

While studies have looked at the accuracy of conductivity data collected by citizen scientists, little formal research looks at the accuracy and consistency of inexpensive, widely available conductivity probes. This study compares conductivity data collected by seven professionally trained scientists using multi-parameter Yellow Springs Instrument (YSI) probes with data obtained using an inexpensive and widely available conductivity meter. Also reported is the long-term reproducibility of conductivity data obtained with the inexpensive meter as an initial indicator of how often this device should be calibrated to maintain data quality. As citizen scientists seek legitimacy for their data, this study aims to justify the use of inexpensive and widely available tools.

Materials and methods

Deciding on a conductivity meter

In 2016, Water Rangers (waterrangers.ca) started to include conductivity meters in their water quality testkits. Testkits are designed to be used by citizen scientists, and so they chose a conductivity meter based on affordability, ease-of-use, and accuracy. Because of this, only pen-type conductivity devices were considered.

Four models were initially considered: (a) HM Digital Meters COM-80 Electrical Conductivity (EC), (b) HM Digital AP-2 Aquapro Water Quality Electrical Conductivity Tester, (c) Andoer

Digital LCD EC Conductivity Meter Water Quality Tester, and (d) Extech EC500 Waterproof ExStik II pH/Conductivity Meter.

In early 2016, the staff biologist at the Ottawa Riverkeeper helped compare these probes to a professional YSI probe calibrated using a standard of 1413 μS/cm. Option (d) was eliminated immediately: it remained inaccurate compared to the professional YSI, even after calibration. The others showed acceptable comparisons, but the interface of (a) was determined to be the most user-friendly. These devices, however, were not fully waterproof, and after initial success, many were destroyed by water damage.

In early 2017, the AZ-836-1 portable conductivity meter, produced by AZ Instrument Corp. in Taiwan and costing approximately $50 CAD, was compared to a professional YSI probe and was ultimately determined to be accurate, user-friendly, and waterproof. The AZ-836-1 model is used in this study.

Comparison to YSI probes

The first part of this research demonstrates the accuracy of the AZ-836-1 model and its comparability to professional YSI probes. Conductivity readings were taken between 2017 and 2019 by water specialists recruited from Water Rangers' network in Eastern Ontario and Western Quebec.

These specialists were employees of Ontario conservation authorities (Rideau Valley (RVCA), Mississippi Valley (MVCA), Cataraqui (CRCA)), professionally trained members of community groups (Watersheds Canada, Fédération des Lacs de Val-des-Monts (FDL)), university students (Carleton University (CU), University of Toronto (UT)), and research scientists at the St. Lawrence River Institute (RI).

Specialists agreed to use the AZ-836-1 model for their water monitoring activities alongside calibrated multi-parameter YSI probes and record results for conductivity, temperature, pH, and dissolved oxygen.

Need for long-term reproducibility

The second part of this study explores how accurate the readings of the AZ-836-1 model remained over time. Values comparing conductivity measurements were taken every 5 days for 50 days by a retired chemist. The experiment consisted of sequentially measuring the conductivity of distilled water, a reference standard, and a White Lake water sample. An equilibration time of 30 seconds was used between measurements. The reference sample was created by measuring a dried weight of sodium chloride and diluting it.

Results

Comparison of results

In total, 58 comparisons were drawn between the professional YSI probes and the AZ-836-1 model.

[Table 1]

The correlation plot produced an R2 value of 0.995. The line’s slope is nearly unity indicating that there was a low bias in the results obtained by either probe type.

[Figure 1]

Precision for long-term reproducibility

For 50 days, the AZ-836-1 meter remained accurate, with a long-term reproducibility, as expressed by a standard deviation of 99.2%. The limit of detection was calculated to be 1.2 μS/cm.

[Table 2]

[Table 3]

Discussion and implications for citizen monitoring

The AZ-836-1 conductivity meter tested in this study is precise and holds its calibration for an extended time compared to professional YSI probes. Determining this is an important first step towards gaining the trust of decision-makers and promoting the expansion of citizen science for water quality monitoring.

Conclusion

Inexpensive and simple tools like the AZ-836-1 conductivity meter can be used by communities in remote regions and groups with limited resources or technical capacity. Conductivity's direct relationship to ecosystem health also offers a way to interpret water quality data that is accessible to those with minimal scientific literacy—as such, providing citizen scientists with a simple, inexpensive tool to collect conductivity data offers them a new way to participate in water conservation and management.

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In accordance with Taylor & Francis policy and my ethical obligation as a researcher, we report that we work at Water Rangers. They use this conductivity meter as part of their water quality testkits. We have fully disclosed those interests to Taylor & Francis, and we have ensured that we have not conducted any of the samples used in its findings.

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Table 1. Comparison of results obtained by the AZ-836-1 meter and professional YSI meters at 58 sample locations in Ontario and Québec (measured in µS/cm)

Organization	AZ-836-1	YSI meters
CRCA	226	208.3
CRCA	181	165.7
CRCA	308	284.6
CRCA	174	160.5
CRCA	363	354.3
CRCA	374	339
CU	381.2	378
CU	1243	1270
CU	210.7	209
CU	90.6	89
CU	372.4	369
CU	204.3	206
CU	265	251
CU	151.3	146
CU	67.5	63
CU	899	885
CU	136.1	134
CU	1409	1440
MVCA	524	538
MVCA	268	177
MVCA	486	497
MVCA	465	477
MVCA	322	338

MVCA	793	807
MVCA	490	504
MVCA	196	206
MVCA	194	207
RI	328	328
RI	315	321.2
RVCA	198	209
RVCA	263	279
RVCA	198	211
RVCA	197	211
RVCA	198	210
RVCA	558	530
RVCA	225	238
RVCA	195	209
FDL	74	83.9
FDL	60	81
FDL	92	107
FDL	61	75.3
FDL	99	116
FDL	91	106.9
FDL	93	107.5
FDL	154	178.8
FDL	70	83.4
FDL	153	172.9
FDL	57	76.1

FDL	83	97.6
FDL	81	97.1
FDL	115	128.8
FDL	103	122.1
UT	61	66.3
UT	70	51
UT	48	41.1
UT	40	43
UT	61	66.8
UT	62	67.3

Table 2. Long-term reproducibility of the AZ-836-1 conductivity meter (measured in μS/cm)

Day	Distilled water	Reference standard	Distilled water	White Lake water sample
1	2	188	2	199
5	2	189	2	200
15	2	187	1	200
20	2	189	1	200
25	2	189	1	200
30	2	189	1	199
35	2	189	2	200
40	2	188	2	200
45	2	188	1	200
50	2	188	1	200

Note. The AZ-836-1 probe was used to measure the conductivity of a distilled water sample twice on each testing day. Day 10 is excluded because the volunteer was unable to test on that day.

Table 3. Average conductivity readings of the AZ-836-1 meter over 50 days (measured in μS/cm)

Sample	Conductivity ± Standard Deviation (n=10)
Distilled water	1.8 ± .4
Reference standard	188.4 ± .7
White Lake water	199.8 ± .4

Figure captions:

Figure 1. *Comparison between AZ-836-1 meter and YSI probes*